

## **STRENGTH FEASIBILITY STUDY OF RECYCLED COARSE AGGREGATE CONCRETE WITH WATER CONTAINING SODIUM HYDROXIDE**

**CHETNA M. VYAS<sup>1</sup>, INDRAJIT. N. PATEL<sup>2</sup> & DARSHANA. R. BHATT<sup>3</sup>**

<sup>1</sup>Assistant Professor & Research Scholar, Department of Civil Engineering, A. D. Patel Institute of Technology,

New Vallabh Vidyanagar, Anand, Gujarat, India

<sup>2</sup>Professor, Department of Structural Engineering, B. V. M. Engineering College,

Vallabh Vidyanagar, Anand, Gujarat, India

<sup>3</sup>Associate Professor, Department of Structural Engineering, B. V. M. Engineering College,

Vallabh Vidyanagar, Anand, Gujarat, India

### **ABSTRACT**

This research paper presents the effect of sodium hydroxide (NaOH) present in the curing water on the strength of Recycled Coarse Aggregate Concrete(RCAC). The concrete is produced by mixing of % replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate and curing water containing NaOH of 5% concentration with constant dosages. This research work describes the feasibility of using the Recycled Coarse Aggregate in concrete production as partial replacement of Natural Coarse Aggregate by weight. The Natural Coarse Aggregate has been replaced by Recycled Coarse Aggregate accordingly in the range of 0% (without Recycled Coarse Aggregate), 20%, 40%, 60%, 80% and 100% by weight of Natural Coarse Aggregate for M-35 grade concrete. The compressive strengths were evaluated for 56 days of normal curing and 28 days normal + 28 days 5% NaOH contain water curing. The results show that, the compressive strength of Recycled Coarse Aggregate Concrete (RCAC) has come down with an increase in the % replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate with constant dosages of 5% concentrated NaOH solution at 56 days. Compressive strengths of Recycled Coarse Aggregate Concrete (RCAC) have decreased in the range of 0.74 to 25.45%, when compared with the control specimens. By using Regression Models the ratio between the experimental compressive strength value and the Regression Models predicted values can be compared.

**KEYWORDS:** Recycled Coarse Aggregate Concrete, Compressive Strength, Regression Models, Sodium Hydroxide

### **INTRODUCTION**

Concrete is a composite construction material composed of cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and/or admixtures. Concrete is made by mixing: Cement, water, course fine aggregates and admixtures (if required). The objectives are to mix these materials traditionally to make concrete that is easy to: Transport, place, compact, finish and to give a strong and durable product. The proportionate quantity of each material (i.e. cement, water and aggregates) affects the properties of hardened concrete.

Concrete is strong and tough material but it is porous material also which interacts with the surrounding environment. The durability of concrete depends largely on the movement of water and gas enters and moves through it.

Although there is a critical shortage of virgin aggregate, the availability of demolished concrete for use as recycled concrete aggregate (RCA) is increasing. Using the waste concrete as RCA conserves virgin aggregate, reduces the impact on landfills, decreases energy consumption and can provide cost savings. Recycled aggregates are the materials for

the future. The application of recycled aggregate has been started in many Western countries and Asian countries for construction projects.

The effects of up to 100% recycled coarse aggregate concrete on a range of durability properties have been established and assessed its suitability for use in a series of various applications. The environmental and economic implications of this are no longer considered sustainable and, as a result, the construction industry is experiencing more pressure than ever before to overcome this practice.

The durability of concrete can be defined as the ability to perform satisfactorily in the exposure condition to which it is subjected over an intended period of time with minimum of maintenance. Durability problems related to environmental causes include the following: steel corrosion, delamination, cracking, carbonation, sulfate attack, chemical attack, scaling, spalling, abrasion and cavitation.

Water is an important ingredient of concrete which affect the durability of concrete water helps to form the strength given cement gel, the quality of water should be critically monitored and controlled during the process of concrete making and concrete hardening which is in actual practice often neglected.

## MATERIALS AND METHODS

### Ordinary Portland Cement

The most common cement used is an ordinary Portland cement. The Ordinary Portland Cement of 53 grades conforming to IS: 8112-1989 is being used. Many tests were conducted on cement; some of them are consistency tests, setting tests, soundness tests, etc.

**Table 1: Properties of Cement**

Sr. No.	Physical Properties of OPC 53 Cement	Results	Requirements as per IS:8112-1989
1	Specific Gravity	3.15	3.10-3.15
2	Standard Consistency (%)	31.5	30-35
3	Initial Setting Time (min.)	30	30 minimum
4	Final Setting Time (min.)	211	600 maximum
5	Compressive Strength (at 7 days in N/mm <sup>2</sup> )	40	43 N/mm <sup>2</sup> minimum
6	Compressive Strength (at 28 days in N/mm <sup>2</sup> )	58	53 N/mm <sup>2</sup> minimum

### Coarse Aggregate (Recycled and Natural Coarse Aggregates)

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are being used. The Flakiness and Elongation Index were maintained well below 15%.



Natural Coarse Aggregate



Recycled Coarse Aggregate

**Figure 1: Natural Coarse Aggregate and Recycled Coarse Aggregate**

**Table 2: Properties of Natural and Recycled Coarse Aggregates**

Sr. No	Particulars	Natural Coarse Aggregate	Recycled Coarse Aggregate
1	Source	Anand, Gujarat	Anand, Gujarat
2	Max. aggregate size	20mm	20mm
3	Specific gravity	2.8446	2.74
4	Fineness modulus	7.086	7.476
5	Density	1805.62 Kg/m <sup>3</sup>	1660.44 Kg/m <sup>3</sup>
6	Impact Value	8%	12.92%

### Fine Aggregate

Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand and crushed sand are being used in combination as fine aggregate conforming to the requirements of IS: 383. The river sand is washed and screened, to eliminate deleterious materials and oversize particles.

**Table 3: Properties of Fine Aggregate**

Sr. No	Particulars	Fine Aggregate
1	Source	Anand, Gujarat
2	Zone	Zone II (IS: 383-1970)
3	Specific Gravity	2.5
4	Fineness Modulus	2.77
5	Density	1752 Kg/m <sup>3</sup>

### Water

Normal water and 5% concentrated NaOH solution with constant dosages is used.

## DESIGN MIX METHODOLOGY

### Design Mix

A mix M35 grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 4.

**Table 4: Concrete Design Mix Proportions**

Concrete Mix	%Replacement of Recycled Coarse Aggregate	W/C Ratio	Proportion	Cement (kg/m <sup>3</sup> )	Fine Aggregates (kg/m <sup>3</sup> )	Coarse Aggregates (kg/m <sup>3</sup> )	Water (lit)
A1	0%	0.40	1:1.06:2.57	479	509.64	1231.33	0
A2	20%	0.40	1:1.06:2.57	479	509.64	985.064	246.266
A3	40%	0.40	1:1.06:2.57	479	509.64	738.798	492.532
A4	60%	0.40	1:1.06:2.57	479	509.64	492.532	738.798
A5	80%	0.40	1:1.06:2.57	479	509.64	246.266	985.064
A6	100%	0.40	1:1.06:2.57	479	509.64	0	1231.33
							191.6

### Alkali Attack Test

This test was carried out on the specimens of 150 x 150 x 150 mm cubes. Total 36 cubes were cast and demoulded after 24 hours. 18 cubes are tested at the ends of 56 days of the normal curing period. 18 cubes are tested at the ends of 56 days (28 days normal + 28 days 5% NaOH contain) water curing period. The specimens were taken out from the curing tank and initial weight was taken.

The concentration of the solution was maintained throughout this period by changing the solution periodically.

The surface of the cylinders was cleaned, weighed and then tested on the compressive testing machine under the uniform rate of loading of 120 kg/cm<sup>2</sup>/min. The changes in strength of the concrete cylinders were calculated as per IS: 516-1959.



**Figure 2: Test Setup for Alkali Attack**

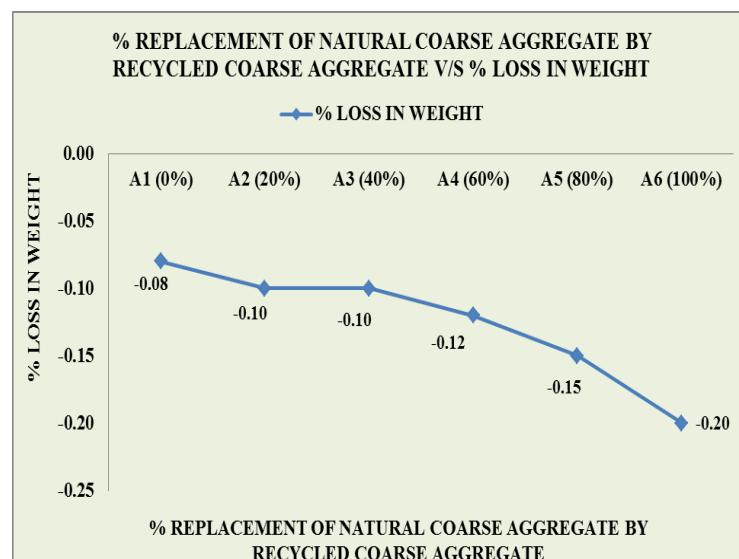
## RESULTS AND DISCUSSIONS

### Effect on Weight of Recycled Coarse AggregateConcrete (RCAC)

The effect of NaOH on the weight of Recycled Coarse Aggregate Concrete is shown in Table 5, from which it is observed that with increases in % replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate the % loss in weight also increases.

**Table 5: Effect on Weight of Recycled Coarse Aggregate Concrete**

Sr. No.	Concrete Mix	% Replacement of Recycled Coarse Aggregate	Oven Dry Weight in Grams (W1)	Wet Weight in Grams (W2)	Loss in Weight % Age
1	A1	0%	8470	8463	- 0.08
2	A2	20%	8470	8461	- 0.10
3	A3	40%	8470	8461	- 0.10
4	A4	60%	8470	8460	- 0.12
5	A5	80%	8470	8458	- 0.15
6	A6	100%	8470	8453	- 0.20



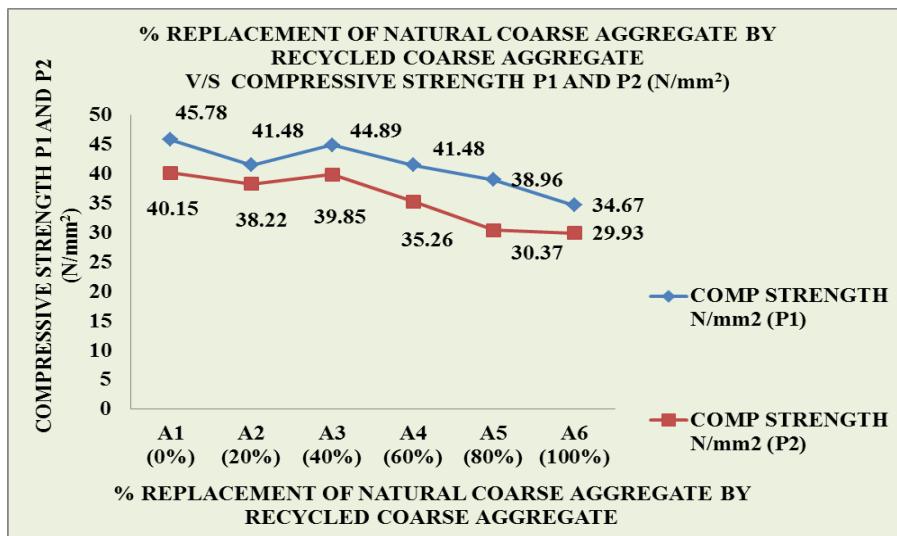
**Figure 3: % Replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate v/s Loss in Weight (%)**

### Effect on Compressive Strength of Recycled Coarse Aggregate Concrete

The effect of NaOH concentration on the compressive strength Recycled Coarse Aggregate Concrete is presented in Table 6.

**Table 6: Compressive Strength of Recycled Coarse Aggregate Concrete corresponding to NaOH Contain Curing**

Sr. No	Concrete Mix	% Replacement of Recycled Coarse Aggregate	Recycled Coarse Aggregate Concrete			% Change in Compressive Strength	
			Compressive Strength N/mm <sup>2</sup> (P1) 150x150x150	Compressive Strength N/mm <sup>2</sup> (P2) 150x150x150	Loss in Compressive Strength % Age (P2-P1/P1) x 100	Compressive Strength N/mm <sup>2</sup> (P1) 150x150x150	Compressive Strength N/mm <sup>2</sup> (P2) 150x150x150
			With Normal Curing of 56 Days	With 28 Days Normal Curing and 28 Days NaOH Contain Curing		With Normal Curing of 56 Days	With 28 Days Normal Curing and 28 Days NaOH Contain Curing
1	A1	0%	45.78	40.15	- 12.30	0	0
2	A2	20%	41.48	38.22	- 7.86	- 9.39	- 4.80
3	A3	40%	44.89	39.85	- 11.23	- 1.94	- 0.74
4	A4	60%	41.48	35.26	- 15.00	- 9.39	- 12.17
5	A5	80%	38.96	30.37	- 22.05	- 14.89	- 24.35
6	A6	100%	34.67	29.93	- 13.67	- 24.26	- 25.45



**Figure: 4 % Replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate V/S Compressive Strength (N/mm<sup>2</sup>) P1 and P2**

Decrease in compressive strength of specimens cured with NaOH solution is observed. The rate of decrease in compressive strength also gradually increases with an increase in the % of Recycled Coarse Aggregate in the concrete. With the % replacement of Natural Coarse Aggregate Concrete by Recycled Coarse Aggregate Concrete 0%, 20%, 40%, 60%, 80% and 100% with normal curing after 56 days the compressive strength of cubes is decreased but parallel the compressive strength with 56 days (28 days normal + 28 days 5% NaOH contain) curing also decreased. The decrease in compressive strength is 13.67% for 56 day concrete.

It was also observed that the Recycled Coarse Aggregate Concrete has shown a noteworthy resistance vis-a-vis the plain concrete. Similar observations were also noticed in the present experimental investigation.

## Regression Models

To estimate the compressive strength of Recycled Coarse Aggregate Concrete(RCAC) exposed to NaOH, two regression models have been developed one each for 56 days M35 grade concrete. The regression models are given below.

$$f_{ck56_1} = 45.246 - 0.0682x \quad \text{Equation (1)}$$

$$f_{ck56_2} = 41.274 - 0.1126x \quad \text{Equation (2)}$$

Where,

$f_{ck}$  = Compressive strength of Recycled Coarse Aggregate(RCAC) in N/mm<sup>2</sup> with normal curing of 56 days

$F_{ck56_2}$  = Compressive strength of Recycled Coarse Aggregate(RCAC) in N/mm<sup>2</sup> with 28 days normal curing + 28 days 5% NaOH contain curing

$$C = \% \text{ replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate}$$

The coefficient of correlation factor for regression equations 1 and 2 is **0.5986** and **0.7655** respectively. The performance of regression models is presented in Table 7.

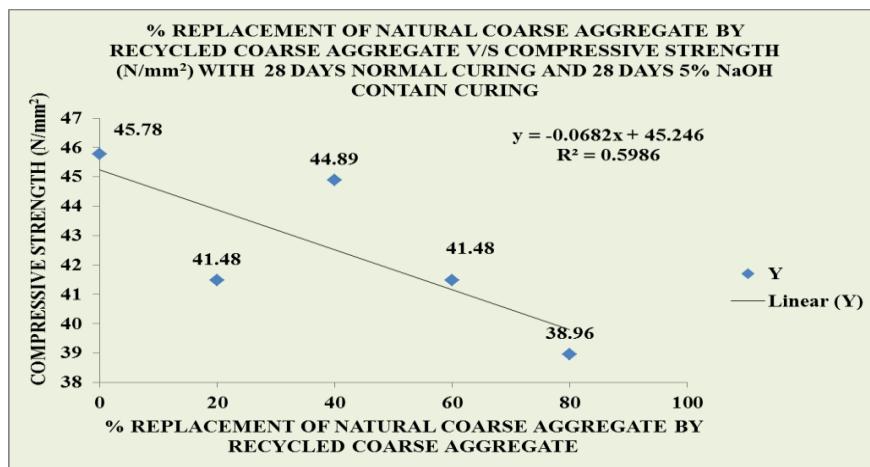


Figure: 5 % Replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate V/S Compressive Strength (N/mm<sup>2</sup>) Normal Curing of 56 Days

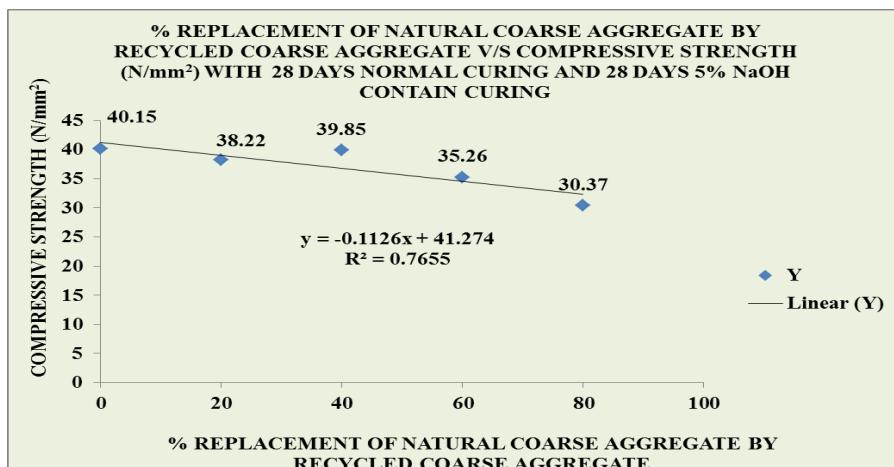


Figure: 6 % Replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate V/S Compressive Strength (N/mm<sup>2</sup>) with 28 Days Normal Curing and 28 days 5% NaOH Contain Curing

**Table 7: Performance of Regression Models for Compressive Strength**

Sr. No.	% Replacement of Recycled Coarse Aggregate	Compressive Strength of Recycled Coarse AggregateConcrete in Mpa with Normal Curing of 56 days			Compressive Strength of Recycled Coarse AggregateConcrete in Mpa with 28 Days Normal Curing and 28 days NaOH Solution Curing		
		Experimental (EXP)	Regression Model (RM)	RM/ EXP	Experimental (EXP)	Regression Model (RM)	RM/ EXP
1	0%	45.78	45.246	0.99	40.15	41.274	1.03
2	20%	41.48	43.882	1.06	38.22	39.022	1.02
3	40%	44.89	42.518	0.95	39.85	36.770	0.92
4	60%	41.48	41.154	0.99	35.26	34.518	0.98
5	80%	38.96	39.790	1.02	30.37	32.266	1.06
6	100%	34.67	38.426	1.11	29.93	30.014	1.00

From above Table-7 the ratios between experimental compressive strength value and the value predicted by the regression model for with normal curing of 56 days are about 0.95 to 1.11 and with 28 days normal curing and 28 days 5% NaOH solution curing are about 0.92 to 1.06 respectively. This implies the proposed models made a good agreement with experimental values.

## CONCLUSIONS

The following conclusions were made from the experimental research work.

- Continuous loss in weight of Recycled Coarse Aggregate Concrete (RCAC) specimens prepared with 0% to 100% replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate is 0.08% to 0.20%.
- Continuous decrease in compressive strength of Recycled Coarse Aggregate Concrete (RCAC) specimens prepared with 0% to 100% replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate when cured by 5% NaOH contain solution is 7.86% to 22.05%.
- Plot of 56 days normal curing Compressive strength against Recycled Coarse Aggregate Concrete (RCAC) specimens is shown in figure 4, for 0% to 100% RCA replacement. The plot shows linear regression and coefficient of regression is 0.5986.
- Plot of 28 days normal curing and 28 days 5% NaOH contain curing Compressive strength against Recycled Coarse Aggregate Concrete (RCAC) specimens is shown in figure 4, for 0% to 100% RCA replacement. The plot shows linear regression and coefficient of regression is 0.7654.
- The proposed regression models show good performance to predict the compressive strength.

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#### AUTHOR'S DETAILS



Mrs. Chetna M. Vyas was born in 1964 in Umreth town. She received her Bachelor of Engineering degree in Civil (Structural) Engineering from the Birla Vishvakarma Mahavidyalaya in 1986. In 2000 she received her Master's Degree in Construction Engineering and Management from Birla Vishvakarma Mahavidyalaya, Sardar Patel University. She joined A.D.Patel Institute of Technology in 2002 as a faculty where she is Assistant Professor in Civil Engineering Department with a total experience of 25 years in the field of Research, Designing and education. She has published papers in National Conferences and International Journals.



Dr. I. N. Patel was born in 1964 in Anand city. He received his Bachelor of Engineering degree in Civil (Structural) Engineering from the Sardar Patel University in 1986. In 2007 he received his Master's Degree in M.E. Structural Engineering from the Sardar Patel University. In 2012 he received his PhD Civil Engineering, SVNIT, Surat, Gujarat. He is working with Birla Vishvakarma Mahavidyalaya, Department of Structural engineering as Professor, with a total experience of 26 years in the field of Research, Designing and education. He has published 12 papers in National Journals /Conferences and 14 papers in International Journals/Conferences.



Dr. Darshana R. Bhatt has completed his graduation in Civil Engineering in 1992, and Post-Graduation and Doctorate in Structural Engineering. She is working with Birla Vishvakarma Mahavidyalaya, Department of Structural engineering as Associate Professor. She has been teaching since last 18 years. She is instrumental in fetching 2 grants worth Rs. 14.0 lcs under AICTE MODROB and R & D grant. Apart from academics, she is involved in consultancy

activities for Research and Testing work in the Department. She has 34 research papers to her credit. She has guided 03 PhD scholars and 14 master level, and 01 UG projects. She registered PhD guide for S.P. University (SPU) and Gujarat Technical University (GTU) and has been performing examiner duties for above universities. She is a life member of Indian Society for Technical Education (ISTE) and the Institute of Engineers (India)